DOCUMENT RESUME

ED 449 184 TM 032 292

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TITLE Characteristics in Restructuring High School Students' Frameworks of Gaseous Kinetics in Korea: A Psychological Point of View.
PUB DATE 2000-04-00
NOTE 33p.; Paper presented at the Annual Meeting of the American Educational Research Association (New Orleans, LA, April 24-28, 2000).
PUB TYPE Reports - Research (143) -- Speeches/Meeting Papers (150)
EDRS PRICE EDRS Price MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS *Concept Formation; Ecology; Epistemology; Foreign Countries; *High School Students; High Schools; Kinetics; Knowledge Level; *Psychological Characteristics
IDENTIFIERS *Conceptual Level; Gases; *Koreans; South Korea

ABSTRACT

This study was conducted to describe in detail Korean students' conceptual change learning processes in the study of kinetic theory of gases. The study was interpretive, using multiple data sources to achieve a triangulation of data. Three students from a public high school for boys served as representative cases. How epistemological aspect and the psychological component of conceptual ecology influenced concept change for these students was studied. The most influential component of conceptual ecology differed according to the conceptual type of the student. There is a need to view both the epistemological and psychological aspects of conceptual change as simultaneously independent and reciprocal and as generated and developed while interacting with each other. The results of this study suggest that conceptual ecology cannot be described from just one point of view. This finding is related to the constructional principle of an individual learner's intellectual environment and the individual's history of learning. (Contains 6 figures, 3 tables, and 15 references.) (Author/SLD)

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Characteristics in restructuring high school students' frameworks of gaseous kinetics in Korea: a psychological point of view

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ED 449 184

TM032292

Poster Presented at the annual meeting of the American Educational Research Association in New Orleans, LA, April 24 - 28, 2000.

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Characteristics in restructuring high school students' frameworks of gaseous kinetics in Korea: a psychological point of view

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Abstract

The present study was conducted to describe in detail Korean students' conceptual change learning processes on kinetic theory of gases within students' conceptual ecology. The study was interpretative, using multiple data sources to achieve a triangulation of data. Three students from a public high school for boys serve as representative cases. In this study, we investigated how epistemological aspect and psychological component of conceptual ecology influenced conceptual change of students. As a result, we suggest that the most influential component of conceptual ecology differs according to conceptual types of students. Consequently, there is a need to view both the epistemological and psychological aspects of conceptual change as to be independent and reciprocal simultaneously, and to be generated and developed while interacting with each other. The result of this study implies that we cannot view or describe conceptual ecology from one point of view. This is related to constructional principle of an individual learner's intellectual environment and individual history of learning.

INTRODUCTION

Since the Conceptual Change Model of Posner, Strike, Hewson and Gertzog(1982, hereafter referred as CCM) has been suggested, many researchers have given praise to this model. The detailed descriptions of the theoretical constructs proposed in the CCM can be found and be extended in Hewson & Thorley (1989), Thorley (1990), Strike & Posner

(1992), Beeth (1993), Park (1995), Thorley & Stofflett (1996), and Beeth & Hennessey (1996).

There are two major components to the CCM. The first of these components is the conditions that need to meet in order for a person to experience conceptual change. The second component is the person's conceptual ecology that provides the context in which the conceptual change occurs, influence the change, and gives it meaning. The conceptual ecology consists of many different kinds of knowledge, the most important of which may be epistemological commitments (e.g., to consistency or generalizability), metaphysical beliefs about the world, and analogies and metaphors that might serve to structure new information.

However, there are some argumentations about CCM: CCM pays little attention on psychological aspect of student learning. This raised the problem of expert-novice transition and of rational, cold conceptual change or contextual, incremental conceptual change (Carey, 1985; Pintrich, Marx, & Boyle, 1993; Demastes, Good, & Peebles, 1995; Tyson, Venville, Harrison, & Treagust, 1997; Vosniadou & Ioannides, 1998). Strike & Posner (1992) emphasized psychological aspect of CCM as well as epistemology and Hewson, Thorley, & Beeth (1998) explained guidelines for CCM as they emphasized the individual learner as being situated in a social and physical context on one hand, while

emphasizing the social environment in which learning activities mediate on the other.

We, therefore, agreed that there is a need to investigate the processes of conceptual change learning to explore individual psychological aspects of learning, we also need to investigate which components of conceptual ecology, including affective domains like motivational beliefs and socio-cultural values, play significant roles on learning on the basis of psychological perspectives.

Purpose of study

The purpose of this study is to investigate and to describe psychological aspects of conceptual change the students have in learning science in according to characteristics of conceptual change that students experience in learning kinetic theory of gases within the theoretical framework of CCM.

Research Methods

Context of this study

The sites chosen for data collection were four classes in a metropolitan public high school in Korea. The study was conducted as a case study, which focused on the concept of kinetic theory of gases.

The students who formed the core of this study were three eleventh grade males. They had been selected by the reference of typical case selection among pre-selected 12

participants. Students discussed topics of lessons and made out their worksheets in a small group cooperative learning environment. The teacher, Mr. M was experienced in teaching high school chemistry for several years. He mostly taught the content of chemistry based on the text. So researchers met Mr. M several times to introduce and discuss the methods of this study and CCM. He made an effort to lead the class in a constructivist-based environment.

Data collections and analysis

This study was implemented in the second semester of 1998 as a naturalistic study; semi-structured and in-depth interviews along with participant observations. We have selected twelve interviewees who differ in achievement score, high, intermediate, and low levels, since we wanted to know about the relationship between academic achievement score levels and conceptual change learning in Korea. Each participant was interviewed individually or in a group four times; in early and pre-instruction, mid, late and after of the semester. Each interview was taken about an hour.

In the first interview, we used seven descriptive concept-test items about kinetic theory of gases, developed on our own to examine the participants' conception of kinetic theory of gases. Students were asked to answer questions and then tell the interviewer the reasons.

In the second and third interviews, students were asked why they answered the way they

did in their worksheets, in order to explore the change of their thinking about kinetic theory of gases. We used the instrument developed by Roth & Roychoudhury (1993) for the participants' conceptions of nature of science, scientific knowledge and chemical knowledge.

In the fourth interview, we used two descriptive concept-test items for which the participants had two response choices: true or false about kinetic theory of gases and gaseous mixture that we developed, which needed to be justified afterwards.

In addition, the interviewer asked the participant how they study science, chemistry in particular, what they think is the most fundamental knowledge of chemistry, what is the most difficult job in learning chemistry, and what kind of environment they want to be learning science.

RESULTS AND DISCUSSION

This research examined the characteristics of change of students' conceptual networks and hence the criteria they determine the status of conceptions and what component of conceptual ecology affect these processes. For this, conceptual networks of students are investigated before and after the instruction by researchers and analyzed to document claims about the component of conceptual ecology, in other words, the role of students' views and perceptions of learning and the role of status.

Organization of Case Studies

This study was implemented by a case study. In monitoring the progress of the conceptual change unit on kinetic theory of gases, we collected data from detailed interviews with 12 students, videotape footage of classroom practices and the assembled written work of all students. In the progress, we found it valuable to focus on three students in detail and construct case studies of their experiences and learning. They provide rich descriptions of the phenomena of teaching and learning. For us, the case studies became the focus for our own evolving understandings of conceptual change learning.

In previous study, we distinguished conceptual types (Cho, Park, & Choi, 1999) of learners by the level of organization and elaboration of conceptual networks students constructed on kinetic theory of gases. This is described in Table 1. They were superficial terms-speaking, partial sense-making, and causal sense-making conceptual types. These three types constitute a spectrum in line but not discrete, and thus sometimes fall into more than one type.

Here about Table 1.

One important aspect of students' viewpoint was that those changed just a small part, therefore had little influence on the changes of students' views of knowing and learning before and after the instructional units, and thus continuously controlled their learning

processes. This implies that it is hard to change students' perspectives of knowing and learning, and this is because their intellectual environments, namely, conceptual ecology is very strict and persistent because of it's own history.

Case Studies

Gu

Is a naive experiential knowledge user as an eclectic (separatist).

Gu distinguishes science for experts and for novices and therefore has confidence that everyday knowledge and school science is not the same. It is hard to experience fundamental conceptual change. He often reserves to judge the status of conceptions and thus is a very passive learner. Especially he distinguishes academic science for future scientists from that for general cultured citizens. He advocates that there is no need to study hard exceedingly beyond one's capability of latent learning power and it is sufficient to study to the extent of passing college entrance exam. His self-efficacy beliefs constrained his confidence in his own ability of learning science and more resistant to new ideas and concepts.

Gu is an eclectic in the result of the test of philosophical viewpoint of science. He thought that only scientists discovered scientific knowledge. He distinguished scientists and general citizen, as the former, discoverer who could understand scientific principles, the

latter, receiptor of the principles. He had strong belief in mechanistic determinism about the nature of scientific knowledge and in the distinction between school and everyday knowledge.

Characteristics of changes of Gu's conceptions on kinetic theory of gases

Before instruction. He could not understand basic scientific knowledge as pieces of conceptual knowledge having scientific meaning. His conceptions were restricted to experiential knowledge. Alternative conceptions he already had constructed lacked internal consistency, and therefore he often gave different explanation according to context.

For example, when he was asked "what will happen to the air in the sealed flask?", he answered "the massive component will sink and the lighter air will rise up." He explained that the larger the size of molecules, the more massive they would be. He could not discuss in such terms as atomic structure, molecule, and molecular weight etc. at the level of conceptual understanding, as he was discussing in terms of everyday knowledge.

He said "gases move freely in the balloon..." to the question of " what are the volumes of oxygen and nitrogen in the flask and balloon?" He could not, however, say the exact volume of component gases but give an answer to the ratio of composition when he was asked to find specific values.

He thought that in the flask, the air existed such that each gas occupied different spaces,

while in the balloon, component gases mixed together because the flask is fixed and the balloon is translatable freely. This acted as a barrier to the connection and incorporation of experiential knowledge and scientific knowledge by the participant, thus causing distinction between school knowledge, which he believed to be rational and everyday knowledge.

Here about Fig. 1.

After instruction. He achieved somewhat enhanced structural development of conceptual network throughout the instructional unit, but the degree of organization and elaboration was still insufficient.

For example, you can see in Fig. 1 and Fig. 2 that he maintained misconception on the uniformity of gaseous mixture before and after the instruction. As to the molecular motion of gases, he related to only molecular weight, but after the instruction, he could explain the motion as being associated with kinetic energy as well as molecular weight. He committed error of causal relations in the explanation of molecular weight when he described average speed, average kinetic energy, and partial pressure of gases as the result of collision number of gases. In addition, he misunderstood the correlation of partial pressure and molar ratios. Finally, the hierarchic structural relations of concepts in conceptual network were not clear, additionally failing to form scientific sense-making of the concepts of scientific terms.

Here about Fig. 2.

Nam

Is a multiple conceptual knowledge user as a rationalist (objectivist, absolutist)

Nam is a partial sense-making type learner. He often uses varied alternative frameworks according to situation, and asserts claims using analogies. His tendency of authority-dependent restricts spontaneous thinking and determination and this operates as an obstacle to conceptual change.

His perspective of knowing and learning is objectivistic. He considered scientific knowledge to be absolute and regard the textbook as a store of knowledge to be memorized and practiced. He does not try to find things out on his own, but always rely on extrinsic authorities like teachers and textbooks. The basis for judgement about status of conception is success or failure in problem solving on ordinary school exam. He strongly retains positivist perspective and believes that all students can do is to accept scientific truth that scientists already found. As a result, he believes that it is necessary to remember all contents of textbook and the statements of teachers. His goal of schooling (learning high school subjects) is to enter college and to get a good job in future. He believes every future job should be related to science and therefore they need to study science.

Characteristics of changes of Nam's conceptions on kinetic theory of gases

Before instruction. He had a clear definition of his own about scientific terms and proper

concepts of scientific knowledge, but these were somewhat unstable, developing alternative framework of such conceptions in addition.

For example, to the question of diffusion of nitrogen and bromine, he said "nitrogen has much less speed because of its smaller molecular weight that diffuse more slowly." Although he knew that the less massive molecules had more speed, his application of the value of speed to diffusion speed was not right. In other words, academic knowledge was not strictly established as scientific knowledge and, therefore, concepts were incompletely constructed. The fact that he could not consider the constancy of average kinetic energy led to indistinctness of hierarchical organization of concepts. Also, he said "because there is an ending point in the diffusion of gases, diffusion can't occur any more and the molecular motion of gases stop at that instance. This is the same with chemical reaction where the reaction stops after the product had been produced." He misunderstood microscopic phenomenon and dynamic equilibrium, also confusing particulate property of matters with linear macroscopic phenomenon. He failed to incorporate experiential knowledge to scientific knowledge, developing and rationalizing alternative frameworks instead.

He thought that pressure decrease in ice water was caused only by the drop in temperature. He could not explain it in relation to average kinetic energy of gas molecules or the inner pressure decrease of balloon. This is the result of mere application of Boyle –

Charles's Law. This indicates that he is apt to apply chemical equations once having successfully learned, and this occurs in spite of situations or contexts. This is considered to be a method of learning and understanding that he developed in order to carry out problem solving. He explained that the inner pressure decrease of balloon in ice water was the same phenomenon as the air pressure decrease experienced when climbing mountains.

His concern is focused on grades whether he can understand the concepts or not. Accordingly, his learning strategy is mainly dependent on rote memorizing contents of text, statements of teacher, workbooks etc. He is highly dependent upon extrinsic authorities and thus a very passive learner.

He has a good deal of fundamental scientific concepts, but cannot organize or systematize them in the conceptual framework as sensible contexts.

For example, he can explain about the molecular size and molecular weight on the basis of atomic size and atomic weight. But to the question of "why are nitrogen and oxygen molecule represented as N_2 and O_2?", "why aren't they represented as N_3 or O_4?", he answered "I just use them because I learned them in middle school." He postponed meaningful sense construction and conceptual understanding, saying, "we learn in school so the knowledge from school is the absolute truth." He lays stress on rote memorizing, and was satisfied with the level of understanding and problem solving which will guarantee a

good academic score.

Here about Fig. 3.

After instruction. He uses multiple perspective representation of reality in the process of generating a better explanation about a task; he can extend his concept and establish hierarchical organization of concepts.

Before learning about the kinetic theory of gases, he thought that the average speed of gas molecule related to its molecular weight, and molecular weight increased with the increase of the number of component atoms. After the instructional unit, he thought that the mixture of gases had a constant average kinetic energy within the condition of constant temperature, and was able to explain the precise causal relationship of average speed and molecular weight. But he confused irregular motion of gases with heterogeneity. As a result, before the instruction he explained the volume of gaseous mixture as "inversely proportional to partial pressure", but afterwards, he answered, " volume of gases increases as the molecular molecules. From this, we can see his particulate perspective is not completely perfect yet, which can be interpreted as the organization of conceptual network that is not yet properly elaborated (Fig. 4).

He rejects the need of reflective thinking, lacks effort of active thinking, and only concentrates on obtaining solution of a given problem. He does not concern scientific

conceptual construction, extension, and elaboration, but interested in acquiring a good grade through simple problem solving by accumulation of fragmentary knowledge.

For example, to the true-false type questions, if he has answered and knew whether it was correct or not, he never tried to prove or falsify it. Even if teacher gave him a question that required a specific answer, he never endeavored but gave answers like "I have already solved the problem."

When he was asked to answer the question "what is the method that makes it possible to know which gas is faster in gaseous mixture of nitrogen and oxygen?" he said, "I don't know" and made no effort to obtain the value.

Here about Fig. 4.

Do

Is a scientific conceptual knowledge user as a constructivist (relativist).

Other students are causal sense-making learners. For this type of learners, conceptual networks develop substantially and systematically via experiencing conceptual change in that new conception interacts effectively with existing conceptual networks. Sometimes especially when he studies new concepts, Do often confuses the situation to be applied pre-constructed interpretive framework. He is interested in learning science and motivated by both learning itself and entrance into college. He evaluates his own learning on the basis of

comprehension of the concept and usually has lots of other disciplinary knowledge.

Consequently his constructivist perspective leads him to use his classroom activities to arrive at new knowledge on his own. He made his effort to seek principles to explain and integrate his ideas and to build more predictive ideas about science.

He tends to compete not only with classmates but also with whole Korean students who take entrance exam at the same year. And he usually chooses subject that he can get best grade as a selective subject for college entrance exam.

Characteristics of changes of Do's conceptions on kinetic theory of gases

Before instruction. He uses concrete and definite terms to explain phenomena, and also understands their scientific meanings well. He makes sensible conceptual network of scientific concepts.

He gave an almost perfect explanation about the state of equilibrium regarding inner and outer pressures of gases when the outer pressure increase causes the inner pressure increase. Interactions in a closed system and the concept about equilibrium were finely constructed in his mind.

He gave explanations on concepts like closed system, average kinetic energy of gases, gaseous pressure, gaseous volume, and their causal relationships. He organized a conceptual framework of scientific knowledge not only in the connection with internal

energy of matters and basic concepts of gaseous kinetics but also applying other disciplinary knowledge such as physics, biology, etc. He maintains explanatory consistency and builds a scientific conceptual network (Fig. 5).

Here about Fig. 5.

After instruction. He is proficient in fundamental scientific knowledge and has the ability to apply other disciplinary knowledge when learning science.

His proper scientific basic conceptions of chemistry make it easy for him to incorporate new concepts to scientific concepts, making it more effective to experience conceptual change learning through Socratic instructional intervention than other conceptual types.

Regarding molecular motion of gases, his fundamental conceptual understanding is well organized and is mixed with other disciplinary knowledge, while he has precise concept of basic gas laws. He comparatively develops and easily extends scientific concepts of gases in the classroom exercises and interviews (Fig. 6).

Intervention by teachers using analogies can provide decisive assistance to cooperate new knowledge to prior conceptions and conceptual network, and consequently to construct scientific concepts.

Despite his initial explanation about the volume of component gases, which was improper, the analogy of two groups of persons made it possible for him to understand the

fact that the volume of component gases was the same with the vessel volume in a closed system, having the same value.

Here about Fig. 6.

Summary

In this study we found that conceptual types of learners would be decided by motivational beliefs that affect learners' perspectives of knowing and learning as well as view of the nature of scientific knowledge.

Consequently we found that the most important component of conceptual change is students' motivational beliefs about learning and this is strongly affected by socio-cultural point of value individual learners have. This psychological viewpoint of learners decides the purpose and strategy of individual learning, and also affects how well the conceptual networks of students organized and elaborated and hence the success or failure in conceptual change learning as in Table 2.

Here about Table 2

Also, student's epistemological beliefs about knowing and learning affect not only the learning strategies employed, but also their stance toward activities in the classroom. The concept of motivation to learn is related to students' goals and learning strategies during task engagement, which in turn influences the quality of their cognitive engagement in the learning activity (Barlia & Beeth, 1999; Lee & Brophy, 1996; Pintrich et al., 1993). These

results are summarized as in Table 3.

Here about Table 3

CONCLUSIONS

As the conceptual networks of students become more developed, it is easier for them to experience substantial, systematic conceptual change. Students often fail to construct mental models of theory because they lack the awareness of the nature of scientific knowledge and fundamental concepts of scientific knowledge. Socio-cultural viewpoint of values and motivational beliefs of individual students as well as their epistemological commitments determine their goals and strategies of knowing and learning. The epistemological commitments also affect conceptual types of students.

Students who exhibit different motivational beliefs engaged with different goals and academic levels in learning tasks, problem solving, and answering questions.

Those who were motivated to learn science and to make a sensible meaning actively demonstrated high quality of engagement. When students pursue learning or task goals, they are interested in learning as an end in itself and seek to understand the task. They are likely to employ deep cognitive and metacognitive strategies and eventually become able to integrate and organize information in their conceptual networks, which result in meaningful

learning and conceptual understanding.

Different goal orientations of students lead them to adopt different inquiry strategies during conceptual change learning. The ways in which students explore, manipulate, fantasize about, ignore, or orient themselves towards objects of learning have an impact on their motivation and ability to engage in sense-making learning activities.

Here we conclude as follows.

From the result of this study, it is proved that the most influential component of conceptual ecology differs according to conceptual types. For example, superficial terms-speaking type student, Gu, has very weak motivational beliefs. He has very low self-efficiency and this strongly affects his epistemological commitments for him to believe that there are two kinds of scientific knowledge, one is for scientists and the other is for the general public. As to the partial sense-making student, Nam, his epistemological commitments about scientific knowledge decides his motivational beliefs. In other words, his objectivistic view of scientific knowledge and beliefs on absolute truths caused him to become a very passive learner and to be dependent strongly on external authorities. That is to say, epistemological component controls psychological component of conceptual change in this case. Causal sense-making student, Do, who has constructivist perspective of learning and knowing, has nearly the same purpose, motivation, and strategy of learning as

those of curriculum, and thus experienced effective conceptual change. In other words, interactive correlation of the aspects of epistemology and psychology acts as a very positive driving force of conceptual change.

IMPLICATIONS

From this study we insist that important component of conceptual ecology is different from learner A to learner B. The most decisive component of conceptual ecology especially differs according to an individual learner.

There has been a criticism about CCM that it stresses its epistemological aspect too much and ignores its psychological aspect, but we suggest this is caused by misunderstanding of the roles and actions of components of conceptual ecology. They are neither independent nor exclusive of each other. Also they cannot be compared to decide which one has the priority.

Consequently, there is a need to view both the epistemological aspect and psychological aspect of conceptual change as to be independent and reciprocal simultaneously, and to be generated and developed while interacting with each other. Thus afterwards, in the study of conceptual change and its relationship with conceptual ecology, kinds of the components of conceptual ecology, their roles in conceptual change, and the way or pattern of their interactions must be investigated.

The result of this study implies that we cannot view or describe conceptual ecology from one point of view. This is related to constructional principle of an individual learner's intellectual environment and individual history of learning.

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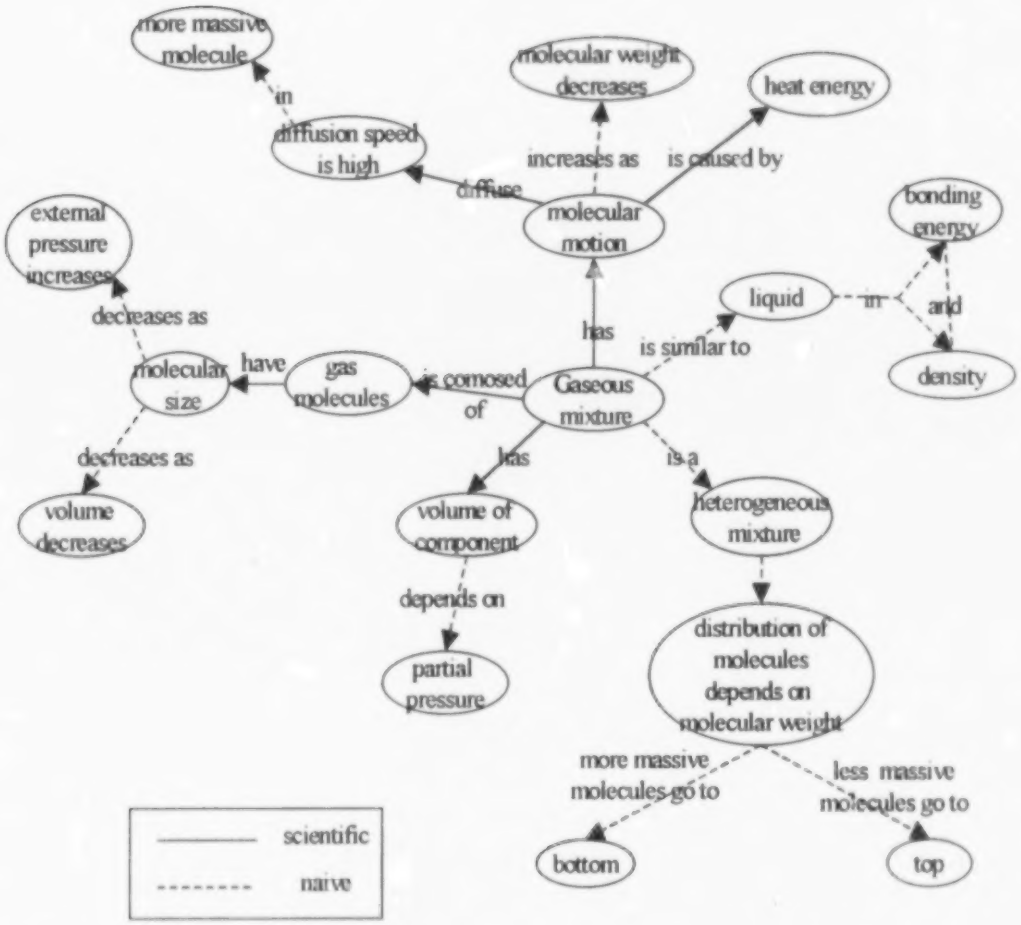

Fig. 1. Gu's conceptual network on kinetic theory of gases before instruction.

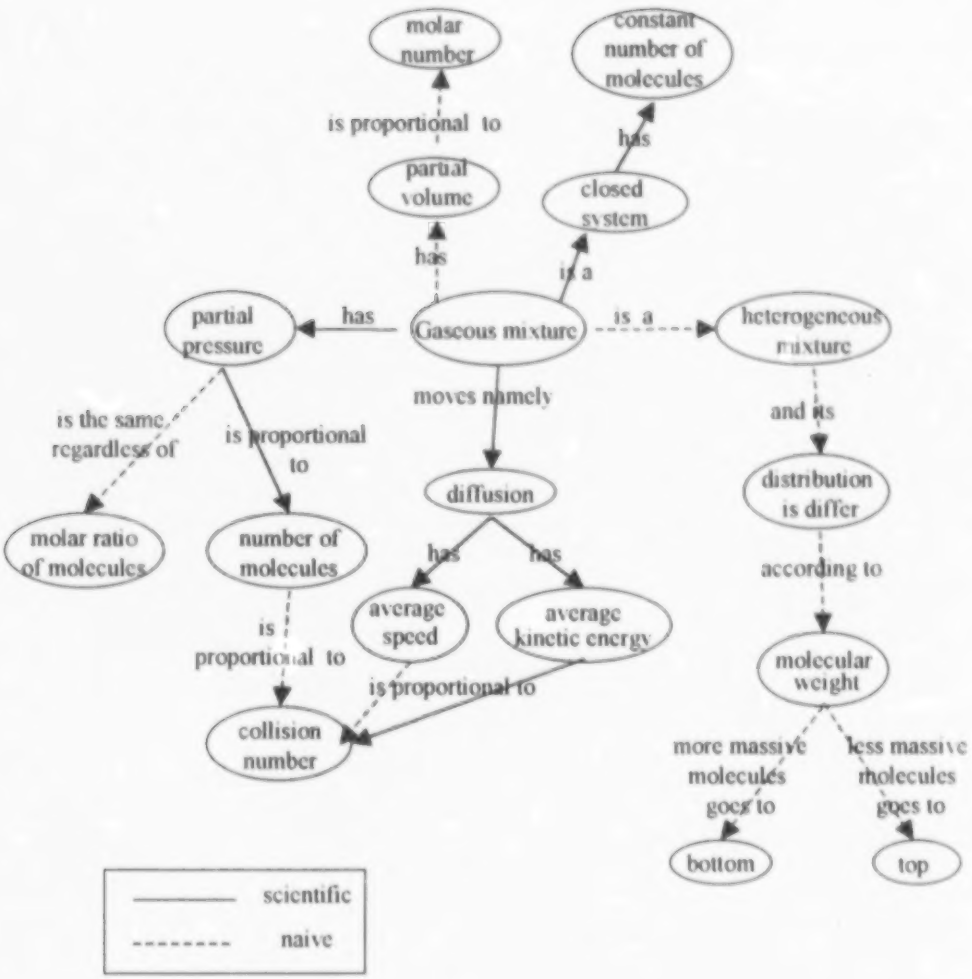

Fig. 2. Gu's conceptual network on kinetic theory of gases after instruction

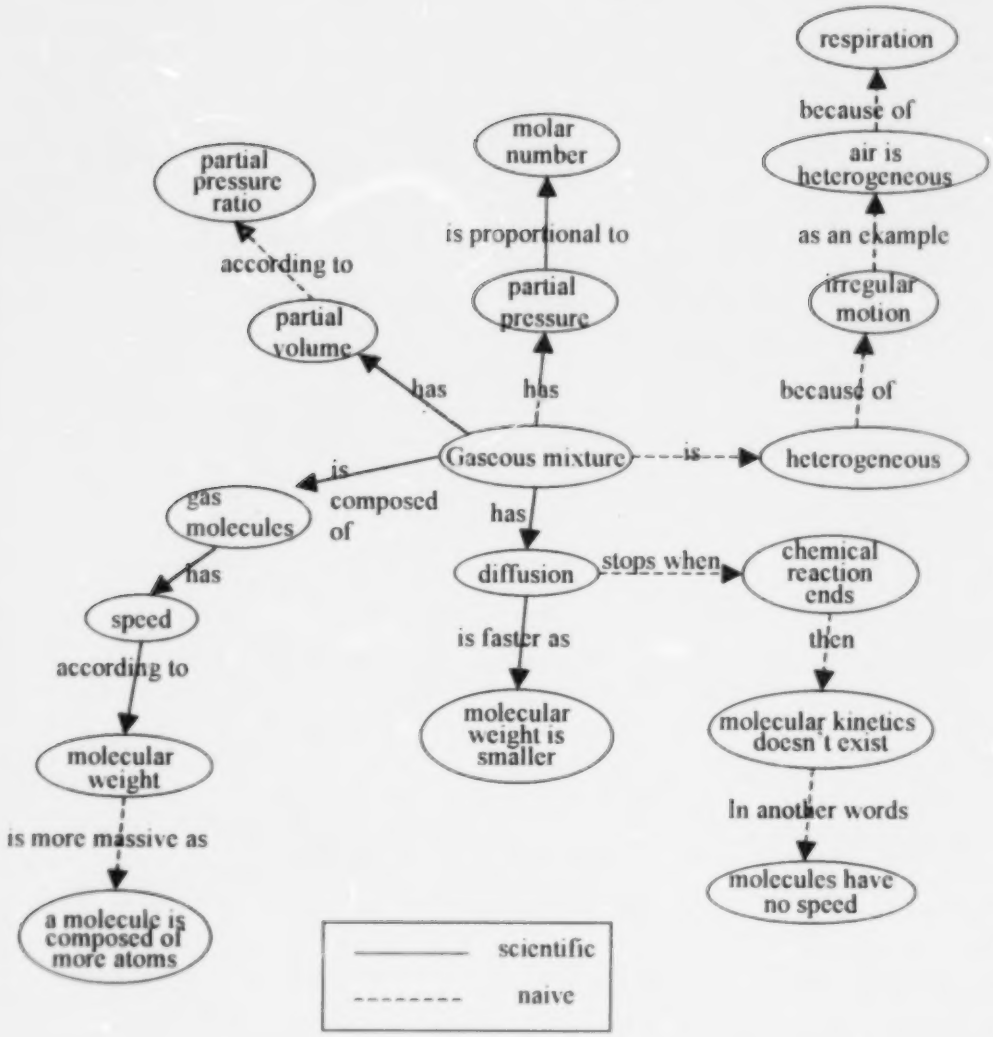

Fig. 3. Nam's conceptual network on kinetic theory of gases before instruction.

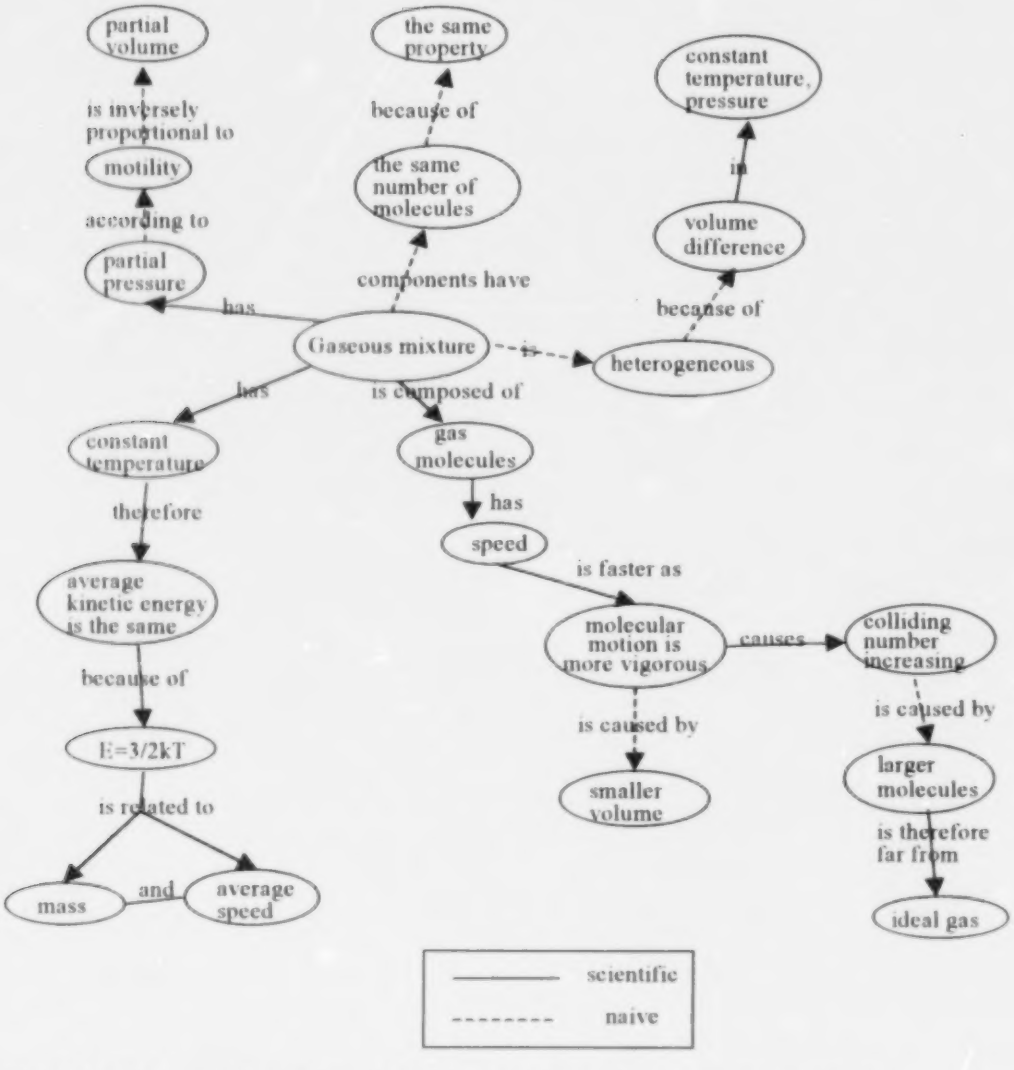

Fig. 4. Nam's conceptual network on kinetic theory of gases after instruction.

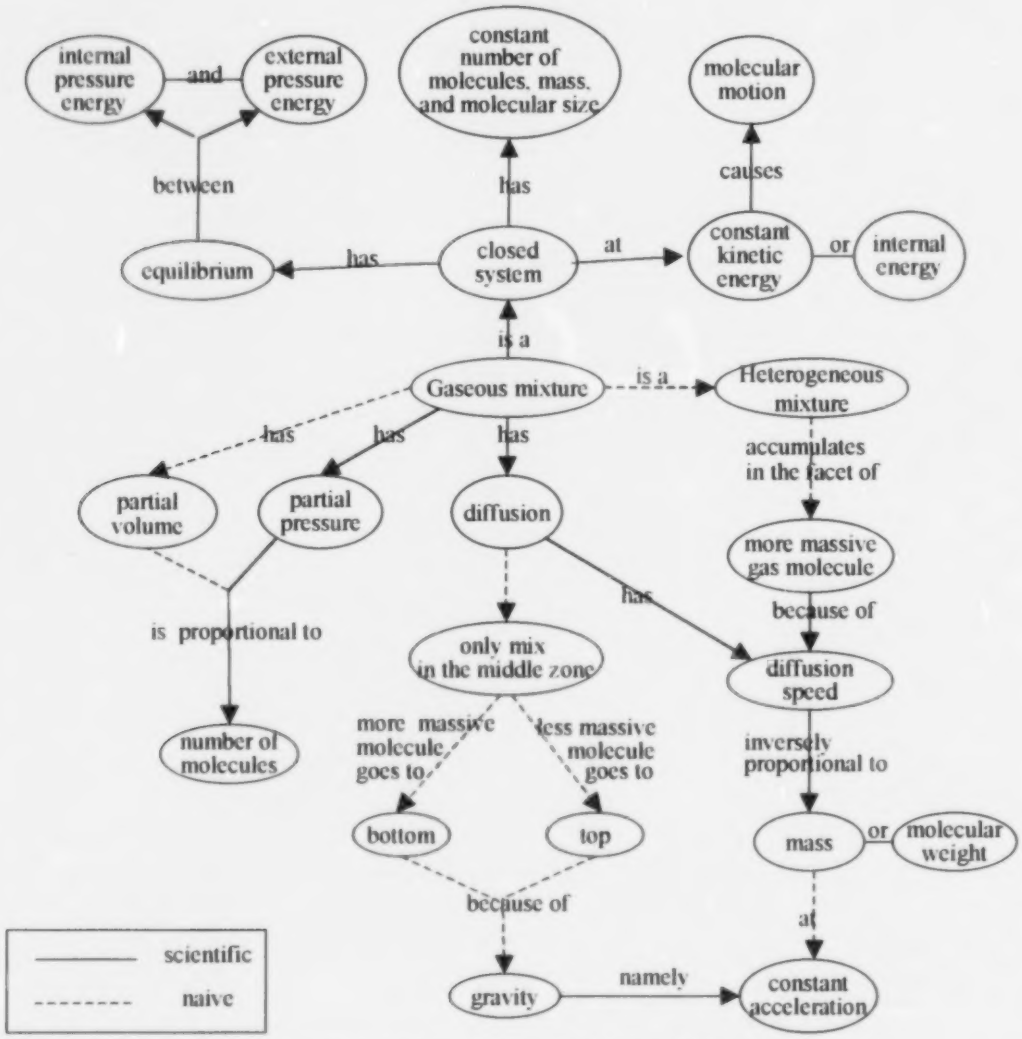

Fig. 5. Do's conceptual network on kinetic theory of gases before instruction.

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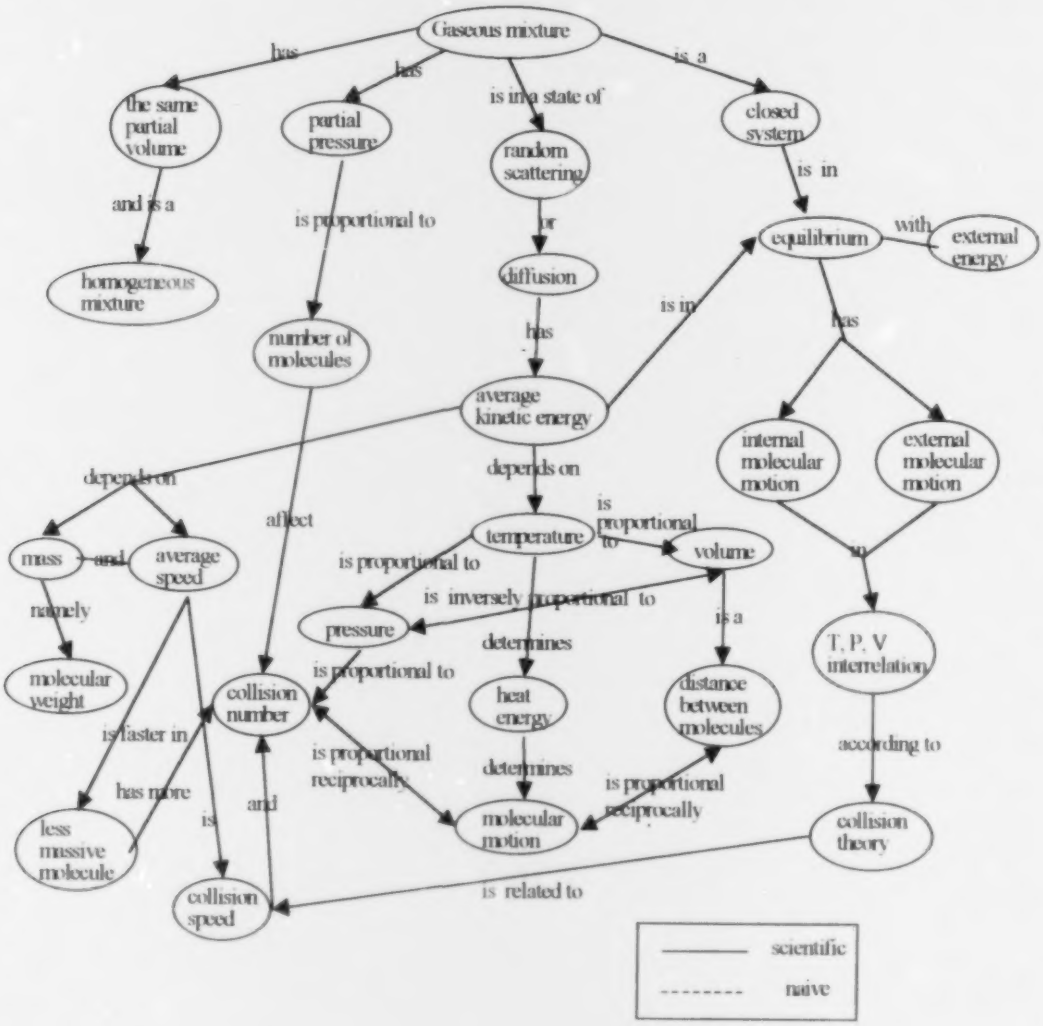

Fig. 6. Do's conceptual network on kinetic theory of gases after instruction.

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Table 1. Conceptual Types of 12 Interviewees and Their Characteristics

Conceptual type	Students	Characteristics
Superficial terms-speaking	Gu Lee Sung Chang Kim	Students in this category can use scientific terms but this is proved to be superficial identification based upon individual experiential knowledge. They usually cannot make sense of the terms based on their scientific understanding. Therefore, the conceptions are not fixed on any conceptual structure, thus failing to form a meaningful conceptual network.
Partial sense-making	Nam Min Ahn	Some students partially have scientific conceptions, but conceptual network is formed locally and is not substantial because of their failure in constructing meaningful context as a whole. Explanatory frameworks of viewing phenomenon are not consistent. It usually seems that empirical and scientific explanations about phenomenological understandings coexist, while scientific knowledge is acknowledged as objective.
Causal sense-making	Do Byun Jin Tae	The other students comparatively construct scientific conceptions. For these students, the hierarchical structure of conceptions is well formed. Other discipline-related knowledge is rich and explanatory consistency is one of the characteristic properties. Therefore stable conceptual network is formed.

Table 2. Summary of Each Participants' Selected Components of Conceptual Ecologies

	Gu	Nam	Do
Epistemological Commitments			
Philosophical Viewpoint of Science	-eclectic	-rationalist	-constructivist
View of the Nature of Scientific Knowledge	-relative truth	-absolute truth, accumulative	-variable
View of Knowing	-being instructed	-discovery, invention	-discovery, invention
View of Learning	-becoming informed	-inheriting truth	-understanding
Viewpoint of Motivational Psychology			
Extrinsic Motivation to Learn	-grade for entrance exam	-grade for entrance exam	-grade for entrance exam
Intrinsic Motivation to Learn	-science for all	-absolute need for scientific knowledge	-intellectual curiosity, necessity of knowing
Internalized Socio-cultural Beliefs			
View of the Necessity of Learning	-concerned with future job	-concerned with future job	-concerned with future job
View of Schooling	-self-efficacy as a successful social member	-self-efficacy as a successful social member	-self-efficacy as a successful social member

Table 3. Students' Views about Knowing and Learning

Dimension	Student		
	Gu	Nam	Do
Epistemological commitment	Eclectic	Mechanistic rationalist	Articulate constructivist
Nature of scientific knowledge	A matter of course takes its own course	Absolute good	To be discovered or invented
Textbook learning Conceptual Motivational	Only to check understanding Moderate	Requires practice and memorization High	Requires understanding and interpretation High
Small-group learning Division of labor Negotiation Understanding	Supports learning Yes To eliminate errors Helpful	Prefers not Yes Prefers not Does not help	Supports learning No For multiple understanding Multiple view
Desired teacher support	Very often	Sometimes	Initially, often
Achievement	Average	High	Very high
Knowledge in other fields	Experiential knowledge	Apparent textbook knowledge	Diverse related knowledge
Chemistry is	Hard to understand Memorization	Lots of work Memorization Problem solving	First consideration in understanding concepts